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# TELL ES-SULTAN (JERICHO): RADIOCARBON RESULTS OF SHORT-LIVED CEREAL AND MULTIYEAR CHARCOAL SAMPLES FROM THE END OF THE MIDDLE BRONZE AGE

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**ABSTRACT.** Samples from Tell es-Sultan, Jericho, were selected for high-precision  $^{14}\text{C}$  dating as a contribution toward the establishment of an independent radiocarbon chronology of Near Eastern archaeology. The material derives from archaeological excavations conducted by K. M. Kenyon in the 1950s. We present here the results of 18 samples, associated stratigraphically with the end of the Middle Bronze Age (MBA) at Tell es-Sultan. Six short-lived samples consist of charred cereal grains and 12 multiyear samples are composed of charcoal. The weighted average  $^{14}\text{C}$  date of the short-lived grains is  $3306 \pm 7$  BP. The multiyear charcoal yielded, as expected, a somewhat older average:  $3370 \pm 6$  BP. Both dates are more precise than the standard deviation ( $\sigma$ ) of the calibration curves and the absolute standard of oxalic acid. Calibration of the above Jericho dates is a bit premature, because several groups are currently testing the accuracy of both the 1986 and 1993 calibration curves. Nevertheless, preliminary calibration results are presented for comparison, based on 4 different calibration curves and 3 different computer programs. Wiggles in the calibration curves translate the precise BP dates into rather wide ranges in historical years. The final destruction of MBA Jericho occurred during the late 17th or the 16th century BC. More definite statements about the calibrated ages cannot be made until the accuracy of available calibration curves has been tested. Development of calibration curves for the Eastern Mediterranean region would be important.

## INTRODUCTION

Charles Warren (1883) carried out exploratory excavations at Tell es-Sultan, Jericho, in 1867 and 1868. The first detailed archaeological excavations were conducted during 1907–1909 and 1911 by Sellin and Watzinger (1913) in an Austrian-German expedition. Their archaeological age assignments were later revised by Watzinger (1926), who concluded that Middle Bronze Age (MBA) Jericho was destroyed by 1600 BC at the latest. Garstang conducted excavations from 1930–1936. He dated the destruction of City IV to the Late Bronze Age and suggested an association with the biblical conquest (Garstang and Garstang 1948). However, Kenyon (1957), who excavated at Jericho from 1952–1958, assigned City IV to the MBA, which ended, in her assessment, *ca.* 1580 BC. She considered the new radiocarbon dating method too crude to be useful in Near Eastern studies after *ca.* 3000 BC, in comparison with archaeological age assessments (Kenyon 1960).

Thus, not many samples from Bronze Age Jericho were  $^{14}\text{C}$  dated. By 1979, 55  $^{14}\text{C}$  dates were obtained, but not a single MBA sample of the tell was included, although 7 MBA dates were acquired from the Tombs (Burleigh 1981). Another 19  $^{14}\text{C}$  dates were measured in 1981, but only 1 (BM-1790) relates to the MBA (Burleigh 1983). Unfortunately, these 19 dates are among those measured in the British Museum laboratory during a period for which a systematic uncertainty has been identified, which affects their reliability (Tite *et al.* 1987; Bowman, Ambers and Leese 1990).

The end of the MBA in the southern Levant is characterized by a large number of destroyed and abandoned archaeological sites (Weinstein 1981, 1991). Dever (1992) has reviewed various interpreta-

tions of these archaeological data. Several scholars, including Kenyon, attribute the widespread destruction to the Egyptian army at the beginning of Dynasty XVIII. Bruins and Mook (1989) expressed the need for an independent  $^{14}\text{C}$  chronology of Near Eastern Archaeology based on a series of new, high-precision  $^{14}\text{C}$  dates, including historical and environmental data, to consider possible relations and interactions (Bruins 1994). We present here 18 new  $^{14}\text{C}$  dates of Tell es-Sultan, based on 16 samples stratigraphically related to the end of the MBA. The material was excavated and labeled during the excavations by Kenyon in the 1950s. Six short-lived samples are composed of charred cereal grains and 10 samples consist of multiyear charcoal. One charcoal sample was split into three fractions, which were dated separately.

## METHODS

The reported samples were analyzed at the conventional  $^{14}\text{C}$  laboratory of the Centre for Isotope Research, Groningen, The Netherlands, in 1991 and 1992. All samples were treated by the acid/alkali/acid (AAA) method, combusted to  $\text{CO}_2$  and purified (Mook and Waterbolk 1985). The samples were counted for 3–4 days to obtain the best possible precision; in most cases, enough material was available to use the large (25-liter) counter. We also report the  $\delta^{13}\text{C}$  values, used for fractionation correction.

## RESULTS

### Multiyear Charcoal

Tamarisk is the predominant wood type of charcoal found on the tell; it is also the most common present-day shrub or small tree in the area (Western 1971; Hopf 1983). The 12  $^{14}\text{C}$  dates of 10 charcoal samples from the end of the MBA gave surprisingly uniform dates (Table 1, Fig. 1). These results confirm  $^{14}\text{C}$  laboratory precision at Groningen and archaeological accuracy with regard to stratigraphic relations. The one exception (GrN-18538) consists of the coarse fraction ( $>0.425$  mm)

TABLE 1. Sample Data and Results

Lab no.	$^{14}\text{C}$ date (yr BP)	$\delta^{13}\text{C}$ (‰)	Run date	Material
GrN-18539	$3312 \pm 14$	-23.09	1991	Grains, <i>Hordeum vulgare</i>
GrN-18542	$3288 \pm 20$	-23.54	1991	Grains, <i>Triticum</i> sp.
GrN-18543	$3331 \pm 18$	-23.31	1991	Grains, <i>Triticum</i> sp.
GrN-18544	$3312 \pm 15$	-23.28	1991	Grains, cereal, fragmented
GrN-19063	$3240 \pm 18$	-23.72	1992	Grains, <i>Hordeum vulgare</i>
GrN-19064	$3375 \pm 25$	-21.86	1992	Grains, cereal, fragmented
GrN-18363	$3365 \pm 25$	-26.28	1991	Charcoal
GrN-18365	$3360 \pm 25$	-24.36	1991	Charred wood
GrN-18367	$3350 \pm 20$	-25.70	1991	Charred wood
GrN-18368	$3393 \pm 17$	-26.02	1991	Charcoal
GrN-18370	$3380 \pm 25$	-25.32	1991	Charcoal
GrN-18536	$3342 \pm 17$	-24.61	1991	Charred wood
GrN-18537	$3384 \pm 15$	-25.98	1991	Charcoal
GrN-19068	$3350 \pm 16$	-25.72	1992	Charcoal
GrN-19223	$3388 \pm 16$	-25.62	1992	Charcoal
GrN-18538	$3614 \pm 20$	-24.53	1991	Charcoal $>0.425$ mm
GrN-18721	$3385 \pm 20$	-24.98	1991	Charcoal $<0.180$ mm
GrN-18722	$3368 \pm 17$	-24.92	1991	Charcoal 0.180–0.425 mm

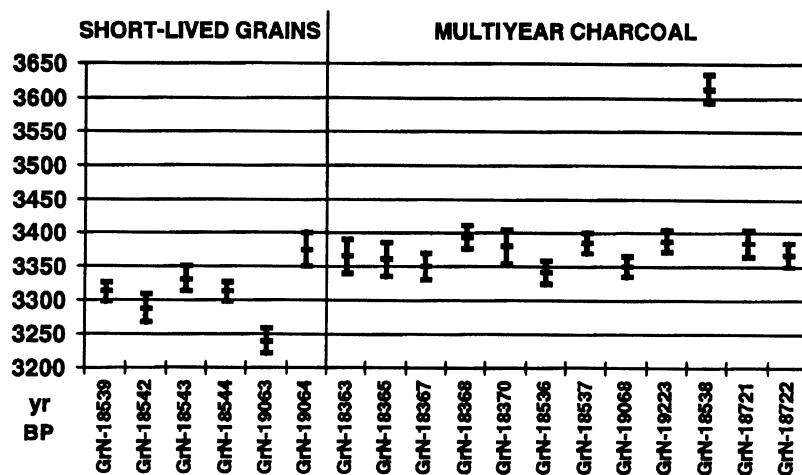


Fig. 1. End of Middle Bronze Age Jericho: <sup>14</sup>C dates in years BP

of a large charcoal sample, which was split in three fractions, dated separately (Fig. 2). The other two fractions (<0.180 mm and 0.180–0.425 mm) yielded dates (3385 ± 20; GrN-18721 and 3368 ± 17; GrN-18722) similar to the nine other samples.

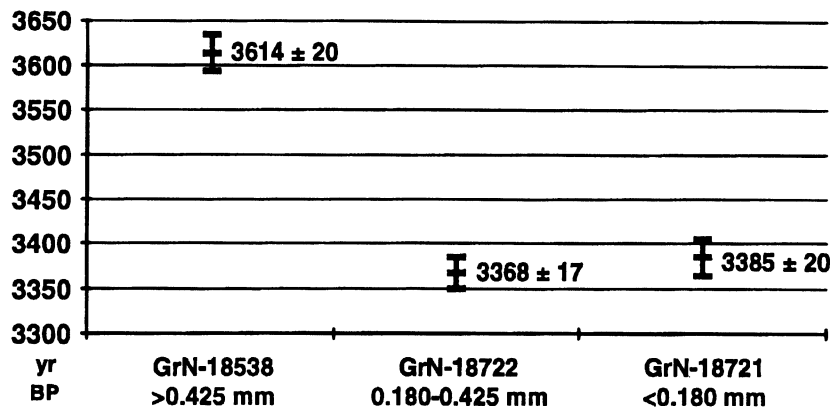


Fig. 2. <sup>14</sup>C dates BP of charcoal sample from Area H (stratigraphy: HAF XII–XIII.Iii.IiiiI), split in 3 fractions.

The high-precision dates have small standard deviations (1  $\sigma$ ), ranging between 15 and 25. The  $\delta^{13}\text{C}$  values range from  $-24.36$  to  $-26.28$ . All the charcoal samples seem to have become charred by the same event, the final destruction and conflagration of MBA Jericho. Kenyon (1981) assigned these samples to stratigraphic phases: HAEiv.XII.liib (occupation levels in rooms) and/or HAF.XII–XIII.Iii.IiiiI (destruction debris of building phase li). This stratigraphic relation coupled with the homogeneous results of the multiyear charcoal dates, excluding GrN-18538, enabled us to calculate a weighted average, according to the formula given by Mook and Waterbolk (1985). The average <sup>14</sup>C date of the 11 charcoal samples has a very small uncertainty:  $3370 \pm 6$  BP. The result probably signifies the last building phase at area H of MBA Jericho, prior to its destruction.

### Short-Lived Grains

The six samples of short-lived cereal grains also yielded homogeneous dates (Table 1, Fig. 1), with standard deviations between 14 and 25. Most of the  $\delta^{13}\text{C}$  values are slightly below  $-23$ , with one exception, a sample of fragmented grains that gave a value of  $-21.86$  (GrN-19064). The charred grains are either wheat or barley, preserved by carbonization, and investigated botanically by Hopf (1983). The samples are all associated with the same event, the final destruction and conflagration that terminated MBA Jericho, *i.e.*, stratigraphic phase HAF.XII–XIII.lii.liii (Kenyon 1981). The results of GrN-18539, -18542, -18543, -18544 are almost identical, again confirming both the contemporary nature of the four samples and the precision of the  $^{14}\text{C}$  measurements. The dates of GrN-19063 and GrN-19064 have a slightly larger spread than the other four, but are still within the  $2\text{-}\sigma$  range (Fig. 1). Most grains probably date to the last harvest preceding the destruction and conflagration of the tell. It is always possible of course that some grains belonged to a reserve storage, a few years older than the last grain harvest. We calculated the weighted average date of the six grain samples, using the formula by Mook and Waterbolk (1985). The resulting date,  $3306 \pm 7$  BP, is both precise and probably accurate to signify the destruction of MBA Jericho in  $^{14}\text{C}$  years (Fig. 3).

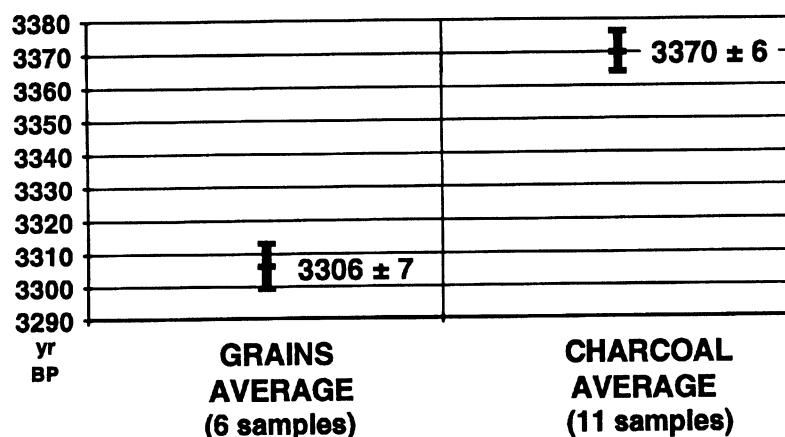


Fig. 3. End of MBA Jericho: Average  $^{14}\text{C}$  dated in years BP of short-lived grains and multiyear charcoal

### CALIBRATION OF WEIGHTED AVERAGES OF GRAIN AND CHARCOAL DATES: A DISCUSSION

The bidecadal calibration curves by Stuiver and Pearson (1986) and Pearson and Stuiver (1986), covering the time period from the present to 2500 BC, were conventionally endorsed (Mook 1986). Corrections were published in 1993 (Stuiver and Pearson 1993; Pearson and Stuiver 1993), but the original data on Irish wood (Pearson *et al.* 1986) may still be valid after all, as discussed by Bowman (1994), who reviewed the state of the art in calibration, its use and regional differences (McCormac *et al.* 1995) between calibration curves. Several groups are currently testing the accuracy of the 1986 and 1993 calibration curves. Therefore, it is a bit premature to make definite statements about the calibration of our very precise  $^{14}\text{C}$  BP results.

The weighted averages of the short-lived grains and multiyear charcoal samples have standard deviations which are smaller than those of the calibration curves and the absolute standard of oxalic acid! However, the very precise BP dates coincide with horizontal segments (wiggles) in all calibration curves used. The preliminary calibrated dates are, therefore, considerably less precise than the BP

date in <sup>14</sup>C years. Ideally, a calibration curve ought to be based on single-year dendrochronological data from the Jericho region, particularly for the calibration of the average grain date. Such a wish is utopian for the time being. However, a preliminary indication of the age in historical years may be obtained from current calibration curves and computer calibration programs. Four calibration curves have been used: the bidecadal 1986 and 1993 versions of Pearson and Stuiver, based on Irish oak chronology (Pearson *et al.* 1986) and German oak chronology (Becker 1993), as well as the decadal 1986 and 1993 versions of Stuiver and Becker, based on German Main-Donau chronology in the required BC time interval. The three computer calibration programs used are CAL20 (previously CAL15) (van der Plicht 1993), CALIB (Stuiver and Reimer 1993) and OxCal (Bronk Ramsey 1995). The latter two programs take account of the standard deviation of the calibration curves. No smoothing of the calibration curve has been used (S=0) in the CAL20 program. The 1986 curves cannot be used in version 3.0.3C of the CALIB program. The calibration results are presented in Figure 4.

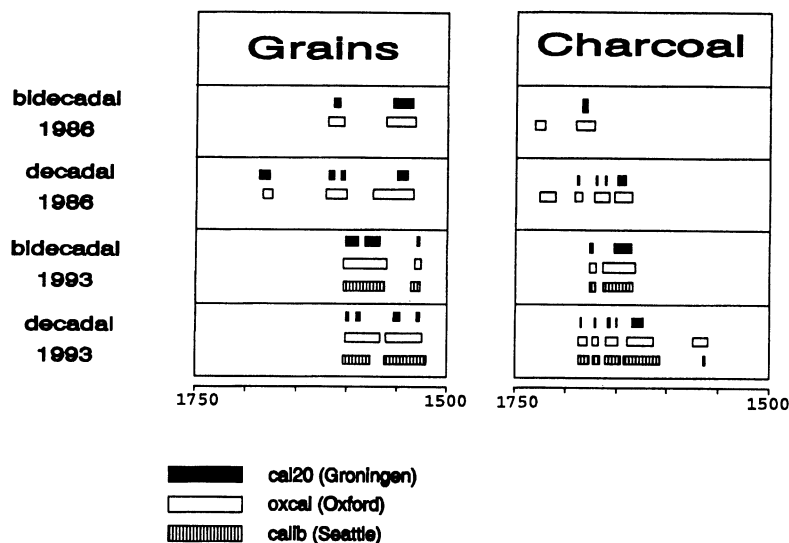


Fig. 4. Preliminary calibration of the weighted average of the grain and charcoal samples, using 4 calibration curves (Pearson and Stuiver 1986, 1993; Stuiver and Becker 1986, 1993) and 3 computer calibration programs (CAL20, van der Plicht 1993; OxCal v2.0, Bronk Ramsey 1995; CALIB v3.0.3C, Stuiver and Reimer 1993).

We have to await further appraisal and reassessment of the above calibration curves before making definite statements about the calibrated results of the Jericho samples. The 1993 version of the bidecadal calibration curve by Pearson and Stuiver gives somewhat younger ages than the 1986 calibration curve. The 1993 version of Stuiver and Becker produces considerably younger dates than their 1986 decadal calibration curve. The 1993 versions of both the bidecadal and decadal calibration curves produce similar dates, but the 1986 versions of these two curves do not give comparable results. Calibrated dates may change with further refinement of both calibration curves and calculation procedures. Therefore, the uncalibrated original BP date *must always* be mentioned with the calibrated result.

The bidecadal curve of Pearson and Stuiver is preferable for the calibration of the weighted average of the multiyear charcoal samples. This date may reflect the last phase of construction of MBA Jericho in Squares H II, III, VI of the tell, designated by Kenyon (1981) as phase XII.li. Using the

OxCal computer calibration program, the 1986 curve gives an age range in the latter part of the 18th century BC and in the 17th century BC: 1732–1722 cal BC (0.24)<sup>1</sup> and 1691–1673 cal BC (0.76). If one chooses the 1993 calibration curve of Pearson and Stuiver, the calibrated result gives two ranges within the 17th century BC: 1678–1670 cal BC (0.24) and 1659–1632 cal BC (0.76).

Calibration of the weighted average of the grain samples results in ranges in both the 17th and 16th century BC, using the 1986 versions of the two calibration curves. With the 1993 versions, the 17th century option becomes negligible, whereas a date in the 16th century is most likely. The decadal calibration curve is recommended by Stuiver and Becker (1993) for short-lived samples formed during a decade or less. Using this calibration curve to calculate the historical date of the weighted average of the grain samples, with the aid of the OxCal computer calibration program, there is equal probability for the 1  $\sigma$  result to be in the range 1601 to 1566 cal BC as in the range 1561 to 1524 cal BC for the destruction of MBA Jericho.

The preliminary calibration results provide valuable new and independent chronological information. The <sup>14</sup>C dates do not support a low 15th century BC chronology for the end of the MBA, as Bimson (1978) proposed. Further, the fortified Bronze Age city at Tell es-Sultan was not destroyed by *ca.* 1400 BC, as Wood (1990) suggested. The archaeological dating of Jericho's destruction by Watzinger (1926) and Kenyon (1957) falls within the preliminary calibrated ranges. However, their archaeological dating is not based on firm chronological evidence but apparently on assumed association with the beginning of the XVIIIth Dynasty in Egypt. This date in the floating Egyptian chronology has gradually shifted from *ca.* 1580 BC (Breasted 1906), used by Kenyon, to the current low chronology of 1539 BC (Kitchen 1987; Ward 1992). It would be extremely valuable to have new sets of high-precision <sup>14</sup>C dates from short-lived material of the Second Intermediate period and the XVIIIth Dynasty in Egypt, to investigate a possible Egyptian connection with the destruction of MBA Jericho. However, the problem and the extent of regional variations between calibration curves need to be addressed. Development of a new high-precision calibration curve for the Eastern Mediterranean region would be ideal, if only the logs could be found.

## CONCLUSION

The two homogeneous data sets of the cereal and charcoal samples indicate that the high-precision BP dates related to the end of MBA Jericho are reliable. The standard deviations of the weighted averages are more precise than the 1- $\sigma$  uncertainty of the calibration curves and the absolute standard of oxalic acid. The charcoal dates are on the average 64 <sup>14</sup>C years older than the cereal dates. Only one charcoal date is an outlier ( $3614 \pm 20$  BP, GrN-18538), for which we have no explanation other than the possibility that the coarse charcoal fragments contained old wood. The weighted average date of the multiyear charcoal ( $3370 \pm 6$  BP) becomes considerably less precise after calibration, due to wiggles in the calibration curves. Preliminary calibration results, depending on the selection of the calibration curve and the computer calibration method, comprise in broad terms the end of the 18th century BC and/or the 17th century BC. The calibrated date of the multiyear charcoal may reflect the time of rebuilding at the Tell (phase XII.li) in Squares H II, III, VI.

The age of the short-lived cereal samples is likely to be within a few years of the destruction date of the last MBA city at Tell es-Sultan. The weighted average of the cereal samples is much more precise in <sup>14</sup>C years,  $3306 \pm 7$  BP, than in historical years, due to wiggles in the calibration curves. Calibration with the 1993 decadal curve of Stuiver and Becker, using the OxCal computer calibration

<sup>1</sup>The number in parentheses after the age ranges signifies the relative probability within the 1- $\sigma$  (68.3%) area.

program, results in 1- $\sigma$  ranges of equal probability, 1601–1566 cal BC and 1561–1524 cal BC. This is one of several options for the calibrated destruction date of MBA Jericho, as shown in Figure 4. The uncalibrated original BP date *must always* be mentioned, because calibrated dates may change with further refinement of both calibration curves and calculation procedures. The preliminary calibration data of the destruction of Tell es-Sultan at the end of the MBA constitute valuable new chronological information, based on detailed and precise <sup>14</sup>C measurements. More definite statements about the calibrated dates can be made only after accuracy tests of existing calibration curves and further assessment of regional variability.

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